Diet of the smooth-hound, *Mustelus mustelus* (Chondrichthyes: Triakidae), in the eastern Adriatic Sea

by

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ABSTRACT. - The diet of the smooth-hound, *Mustelus mustelus*, in the eastern Adriatic Sea was investigated with respect to fish size and season. Stomach contents of 139 specimens, 67 to 137 cm in TL, collected by bottom-trawl from 2001 to 2003 were analyzed. Of the total number of stomachs examined, 24 were empty (17.2%). The prey items identified in stomachs belong to eight major groups: Cephalopoda, Polychaeta, Nemertina, Stomatopoda, Decapoda, Enteropneusta, Tunicata and Teleostei. Decapod crustaceans were the most abundant prey (%IRI = 63.1) especially for individuals up to 110 cm TL. Teleosts were second in importance (%IRI = 31.2), whereas other prey groups were of minor importance and were probably incidentally ingested food. At the species level, the decapods *Atelecyclus rotundatus* (%IRI = 6.7) and *Munida rugosa* (%IRI = 4.3) followed by the teleost *Sardina pilchardus* (%IRI = 2.7) were the most frequent prey. With *M. mustelus* growth, the proportion of decapods decreased whereas that of teleosts and cephalopods increased. Diet composition showed little seasonal variation; decapods were the most important prey taxon in all seasons, especially in summer. The results indicate that the smooth-hound feeds on a wide range of prey items and can be considered an opportunistic predator.

RÉSUMÉ. - Alimentation de l'émissole lisse, *Mustelus mustelus* (Chondrichthyes: Triakidae), en mer Adriatique.

Le régime alimentaire de l'émissole lisse, *Mustelus mustelus*, a été étudié en fonction de la taille des poissons et de la saison. Les contenus stomacaux de 139 spécimens, 67-137 cm TL, capturés par chalutages entre 2001 et 2003, ont été analysés. Sur l'ensemble des estomacs étudiés, 24 étaient vides (17,2%). Le contenu stomacal de *M. mustelus* s'est avéré composé de 8 groupes principaux de proies : céphalopodes, polychètes, némertes, crustacés stomatopodes, crustacés décapodes, entéropneustes, tuniciers, et téléostéens. Les crustacés décapodes constituent les proies principales (%IRI = 63,1), surtout parmi les classes de taille inférieures à 110 cm LT. Les téléostéens sont des proies secondaires (%IRI = 31,2), alors que les autres groupes représentent une nourriture occasionnelle. Au niveau spécifique, les décapodes *Atelecyclus rotundatus* (%IRI = 6,7) et *Munida rugosa* (%IRI = 4,3) puis le téléostéen *Sardina pilchardus* (%IRI = 2,7) ont été les plus fréquents. La proportion de décapodes diminue avec la croissance, tandis que celle des téléostéens et des céphalopodes augmente. La composition du régime alimentaire montre peu de variation saisonnière: les décapodes ont été dominants quelles que soient les saisons, et particulièrement pendant l'été. Les résultats indiquent que l'émissole lisse s'alimente a partir d'un large éventail de proies, et qu'elle peut être considérée comme un prédateur opportuniste.

Key words. - Triakidae - *Mustelus mustelus* - MED - Adriatic Sea - Diet.

The smooth-hound, *Mustelus mustelus* (Linnaeus, 1758), is common throughout the Mediterranean (except Black Sea) and eastern Atlantic (from Great Britain to south Africa) (Compagno, 1984). It is very common in the Adriatic Sea, mostly in the coastal areas and channel above sand and muddy bottoms up to 200 m in depth (Jardas, 1996). The smooth-hound is viviparous fish with size at birth about 40 cm TL (Jardas, 1996). Although different aspects of its biology have been studied in the Adriatic Sea (Karlovac, 1978; Jardas, 1984; Županović and Jardas, 1989; Pallaoro *et al.*, 2005) studies of diet have been rare, are generally not current, and have dealt only qualitative aspects. Published information only provided qualitative reports that bottom-living crustaceans, cephalopods and teleosts are the main dietary components (Županović and Jardas, 1989; Jardas, 1996). The literature referring for other zones is also not extensive. In the Mediterranean Sea, Capapé (1975), Cortés (1999) and Kabasakal (2002) provide some data on the diet of this species, and Morte *et al.* (1997) quantified the diet more thoroughly by calculating the occurrence of prey items. In South African waters, Smale and Compagno (1997) and Smale *et al.* (2001) revealed importance of crustaceans and cephalopods in the diet of smooth-hound.

The purpose of the present study was to examine the diet of the smooth-hound in the eastern Adriatic Sea. The effects of predator size and season on stomach contents were included to provide a more comprehensive examination of the trophic ecology of this species.

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MATERIAL AND METHODS

Smooth-hound (*M. mustelus*) stomach samples were taken from four localities in the eastern Adriatic at depths between 70 and 160 m (Fig. 1). Sharks were sampled from commercial bottom-trawls using a 22 mm stretched mesh cod-end. Duration of each haul was 2-3 h and trawling speed fluctuated from 2-3 knots. A total of 139 specimens were collected between January 2001 and January 2003: 41 specimens during winter (January-March), 32 during spring (April-June), 30 during summer (July-September) and 36 during autumn (October-December). The total length (TL) of sharks was measured to the nearest 1.0 cm and weighted to the nearest 1.0 g. Immediately after capture, fish were dissected and the stomach removed and preserved in a 4% formalin solution to prevent further digestion. Evidence of regurgitation during capture was never observed. In the laboratory, identification of prey was carried out to the species level whenever possible. We counted the prey items and weighted them to the nearest 0.001 g after removal of surface water by blotting paper. Total length of sharks examined ranged from 67 to 137 cm (Fig. 2). To assess for possible changes in diet with respect to size, fish were divided into three size-classes: small (< 90 cm, N = 33), medium (90-110, N = 45) and large (> 110 cm, N = 37). Sample size sufficiency with respect to size-classes and seasons were assessed by cumulative prey curves and *a priori* power analysis (Hurtubia, 1973; Cohen, 1988; Ferry and Cailliet, 1996). After defining the size categories, an adequate number of samples were collected to precisely describe diet.

Numerous indices have been used to quantify the importance of different prey items in the diet of fish (Berg, 1979; Hyslop, 1980; Tirasin and Jørgensen, 1999). In the present study, the following indices were used:

Percentage frequency of occurrence (%F) = number of stomachs in which a food item was found, divided by the total number of non-empty stomachs, multiplied by 100;

Percentage numerical abundance (%Cn) = number of each prey item in all non-empty stomachs, divided by the total number of food items in all stomachs, multiplied by 100;

Percentage gravimetric composition (%Cw) = wet weight of each prey item, divided by the total weight of stomach contents, multiplied by 100.

The main food items were identified using the index of relative importance (IRI) of Pinkas *et al.* (1971), as modified by Hacunda (1981): IRI = %F x (%Cn + %Cw)

The index was then modified after Carrasson *et al.* (1992): %IRI = (IRI/ ∑ IRI) x 100

Statistical differences ($p < 0.05$) in diet composition with respect to size and season were assessed by a chi-square test (Sokal and Rohlf, 1981), applied on the frequency of a given prey.

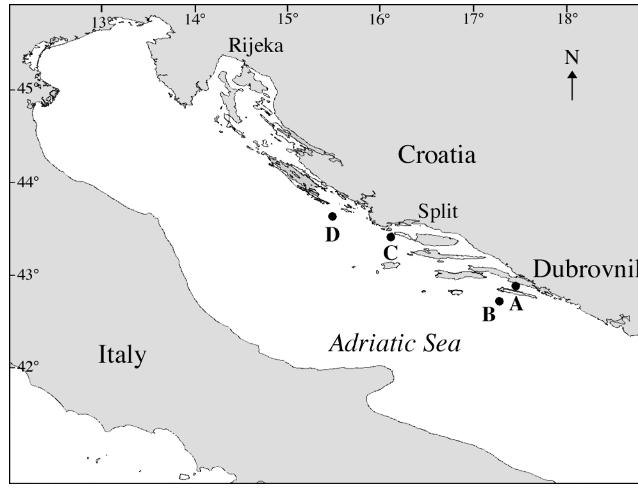

Figure 1. - Study area and sampling localities in the eastern Adriatic. A: Mljet channel: B: south of Lastovo and Mljet islands; C: south of Maslenica; D : Blitvenica fishing area. *[Zone d'étude et localités de captures de* M. mustelus *en mer Adriatique.]*

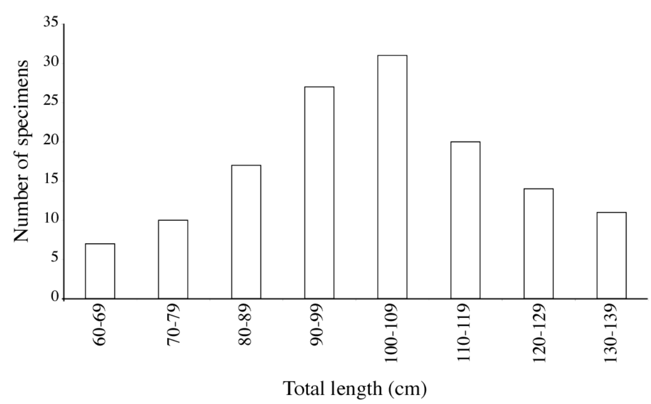

Figure 2. - Length - frequency distribution of *Mustelus mustelus* caught in the eastern Adriatic Sea (n = 139). *[Distribution des fréquences de taille des 139 spécimens de* M. mustelus *capturés en mer Adriatique.]*

Proportional food overlap between size classes and diurnal cycle was calculated using Schoener's (1970) dietary overlap index: $C_{xy} = 1 - 0.5 \sum (P_{xi} - P_{yi})$, where P_{xi} and P_{yi} are the proportion of prey i (based on %IRI) found in the diet of groups x and y. This index ranges from 0 (no prey overlap) to 1 (all food items in equal proportions). Schoener index values above 0.6 are usually considered to indicate significant overlap (Wallace, 1981).

RESULTS

Diet composition

Of the 139 smooth-hound, *Mustelus mustelus* (Linnaeus, 1758) stomachs examined, 24 were empty (17.2%). Among the remaining 115 samples, the diet consisted of eight major

systematic groups: Cephalopoda, Polychaeta, Nemertina, Stomatopoda, Decapoda, Enteropneusta, Tunicata and Teleostei (Tab. I). Decapod crustaceans were the most important prey, constituting 63.1% of the total IRI, followed by teleosts (%IRI = 31.2). The relative importance of cephalopods, polychaetes, stomatopods, nemertina, enteropneusta, and tunicates was comparatively low. It should be noted that, as a result of the advanced degree of digestion of the prey, determination to the species level often was not possible. The two most common identifiable prey items were the decapods *Atelecyclus rotundatus* (%IRI = 6.7) and *Munida rugosa* (%IRI = 4.3) followed by the teleost *Sardina pilchardus* (%IRI = 2.7).

Table I. - Diet composition of 115 stomachs of *Mustelus mustelus* containing food (%F is frequency of occurrence; %Cn is percentage numerical composition; %Cw is percentage gravimetric composition; IRI is index of relative importance). *[Composition alimentaire de 115 estomacs de* Mustelus mustelus *contenant de la nourriturre (%F = pourcentage d'occurrence; %Cn = pourcentage de la composition numérique; %Cw = pourcentage de la composition pondérale; IRI = index d'importance relative).]*

Food items	(%F)	(%Cn)	(%Cw)	IRI	% IRI
Cephalopoda					
Illex illecebrosus	8.85	3.57	2.10	50.1	0.7
Loligo vulgaris	4.11	2.40	1.41	15.6	0.2
Ommatostrephes sagittatus	2.66	1.40	1.25	7.0	0.1
Sepiola sp.	2.15	1.17	1.15	5.0	< 0.1
Unidentified Cephalopoda	5.50	2.33	0.88	17.6	0.2
Total Cephalopoda	14.25	10.87	6.79	251.6	3.5
Polychaeta					
Aphrodite aculeata	6.87	4.72	2.38	48.7	0.6
Unidentified Polychaeta	3.45	0.79	0.01	2.7	< 0.1
Total Polychaeta	8.10	5.51	2.39	64.0	0.8
Nemertina					
Unidentified Nemertina	2.66	3.15	0.52	9.7	0.1
Crustacea					
Stomatopoda					
Squilla mantis	7.10	2.36	1.67	28.6	0.4
Squilla sp.	4.87	2.36	1.22	17.4	0.2
Total Stomatopoda	9.23	4.72	2.89	70.2	0.9
Decapoda					
Atelecyclus rotundatus	20.45	14.51	9.27	486.3	6.7
Munida rugosa	17.15	11.90	6.12	309.0	4.3
Liocarcinus depurator	9.80	4.57	5.39	97.6	1.3
Nephrops norvegicus	8.10	3.85	4.73	69.5	0.9
Liocarcinus sp.	6.58	2.25	2.55	31.6	0.4
Goneplax rhomboids	5.45	2.90	1.69	25.0	0.3
Xantho poressa	3.95	2.27	1.55	15.0	0.2
Pontocaris cataphractus	2.90	1.05	1.35	6.9	0.1
Unidentified Decapoda	14.60	4.73	6.21	159.7	2.2
Total Decapoda	52.32	48.03	38.86	4546.0	63.1
Enteropneusta					
Unidentified Enteropneusta	2.40	0.79	0.20	2.3	< 0.1
Tunicata					
Unidentified Ascidia	2.40	1.57	0.55	5.0	< 0.1
Teleostei					
Sardina pilchardus	12.48	5.27	10.54	197.3	2.7
Engraulis encrasicolus	11.80	3.57	6.26	116.0	1.6
Trisopterus minutus capelanus	6.25	3.57	5.17	54.6	0.7
Trachurus trachurus	3.18	2.79	4.75	23.9	0.3
Trachurus mediterraneus	2.95	2.17	4.55	19.8	0.2
Boops boops	2.95	1.40	3.42	14.2	0.2
Spicara maena	2.66	1.40	2.55	10.5	0.1
Merluccius merluccius	2.15	1.17	1.55	5.8	< 0.1
Unidentified Teleostei	8.45	4.01	8.98	109.7	1.5
Total Teleostei	30.70	25.35	47.77	2244.7	31.2

Food in relation to specimen size

Dietary comparisons between size-classes have shown that estimated sample size is less than actual sample sizes in categories compared ($n' < n_1, n_2, n_3$). Diet composition for size classes of the eight main prey groups is shown in figure 3. Index of Relative Importance varied with specimen size. Decapods were the most important prey group in size classes up to 110 cm TL. The IRI of Decapoda, Stomatopoda, Nemertina and Polychaeta decreased with fish size, whereas the IRI of Teleostei and Cephalopoda increased. In the large size classes (> 110 cm TL) Teleostei represented more than 50% of total IRI. A chi-square revealed non-significant differences between ingestion of Nemertina ($\chi^2 = 1.1$, $p > 0.05$), Enteropneusta ($\chi^2 = 0.9$, $p > 0.05$) and Tunicata ($\chi^2 = 0.5$, $p > 0.05$).

Schoener's index was obtained from comparison (by IRI) of trophic spectrum between size classes. High dietary overlaps were observed between small (< 90 cm) and medium size classes (90-110 cm). Diet of specimens in those size classes consisted mostly of decapods. Values of Schoener's overlap index (< 0.6) reveal quantitative differences in diet between specimen up to 110 cm TL and larger individuals (> 110 cm) (Tab. II).

Seasonal variation in the diet composition

Decapods were dominant prey group in all seasons, particularly in summer (%IRI > 70; Fig. 4). Teleosts were present in the diet throughout the year, with a peak in the winter. Cephalopods, polychaetes, stomatopods, nemertina, enteropneusta and tunicates were present in the stomach contents during all seasons, but in smaller quantities (Fig. 4). Significant differences among all seasons were found only for teleosts ($\chi^2 = 12.6$, $p < 0.05$) and decapods ($\chi^2 = 10.3$,

Table II. - Proportional food overlap coefficients (Schoener's index) of the diet between size classes of *Mustelus mustelus*. *[Taux de chevauchement des régimes alimentaires (indice de Schoener) entre les classes de taille de* M. mustelus.*]*

Size class (cm)	< 90	90 - 110	> 110
< 90	-		
90 - 110	0.69	-	
> 110	0.41	0.55	-

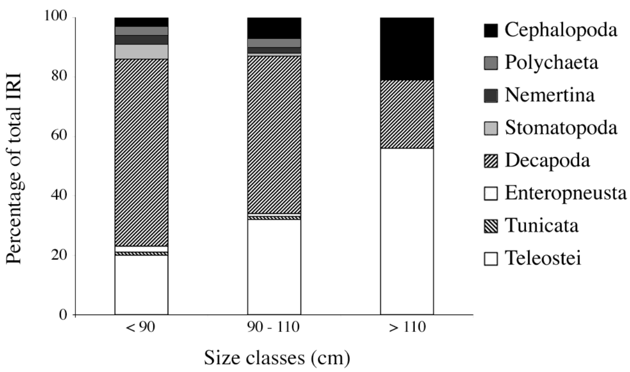

Figure 3. - Composition of *Mustelus mustelus* diet among size classes based on the % IRI values of the major prey groups. *[Composition de l'alimentation de* M. mustelus *en fonction des classes de taille, fondée sur les valeurs des % d'IRI des principaux groupes de proies.]*

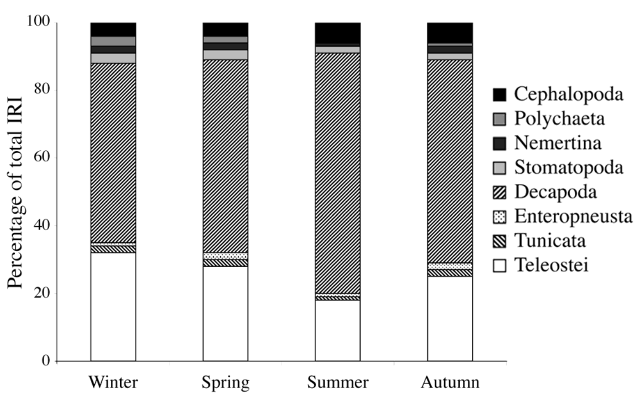

Figure 4. - Seasonal variation of *Mustelus mustelus* diet based on the %IRI values of the major prey groups. *[Variation saisonnière du régime alimentaire de* M. mustelus, *fondée sur les valeurs des % d'IRI des principaux groupes de proies.]*

$p < 0.05$).

High values of food overlap coefficients were observed between spring and winter (0.91) and between summer and autumn (0.90). However, Schoener's index indicating high degree of diet overlaps between any season (Tab. III).

Table III. - Seasonal proportional food overlap coefficients (Schoener's index) of the diet of *Mustelus mustelus*. *[Taux de chevauchement saisonnier des régimes alimentaires (indice de Schoener) chez* M. mustelus.*]*

Seasons	Winter	Spring	Summer	Autumn
Winter	-			
Spring	0.91	-		
Summer	0.81	0.87	-	
Autumn	0.90	0.85	0.90	-

DISCUSSION

This study indicates that decapods were the most abundant prey group of *M. mustelus* in the eastern Adriatic Sea. This prey group, which represents more than 50% of total IRI, can be classified as a "main food" (Rosecchi and Nouaze, 1987). Decapods are also significant source of food for other Adriatic elasmobranchs, including *Scyliorhinus canicula*, *Squalus acanthias*, *S. blainvillei*, *Raja miraletus* and *R. clavata* (Jardas, 1972a; 1972b). Teleosts such as *Sardina pilchardus* and *Engraulis encrasicolus* were secondary prey of *M. mustelus* examined in our study. Other prey such as cephalopods, polychaetes, nemertina, stomatopods, enteropneusta and tunicates were of minor importance and represented incidental food.

Our study indicates that *M. mustelus* in the Adriatic feed mainly on benthic crustaceans that live on the sand and soft bottom sediment, but they also feed on pelagic and benthopelagic teleosts. Although data on smooth-hound diet in the eastern Adriatic Sea are few, Županović and Jardas (1989) found only decapods (mainly *Nephrops norvegicus* and species of *Macropipus* and *Galathea* genera) as prey items. Jardas (1996) also reported that cephalopods and teleosts were consumed by *M. mustelus*. Tortonese (1956), Bini (1967) and Branstetter (1986) reported that in the Mediterranean along the coast of Italy and eastern Atlantic *M. mustelus* feed on molluscs and polychaetes in addition to crustaceans and teleosts. Cephalopods (species of *Loligo* and *Ilex* genera) are the common prey items of smooth-hound in the Aegean Sea (Kabasakal, 2002) and South African waters (Smale *et al.*, 2001).

Capapé (1975) found that decapods (mainly *Brachyura*) were the primary prey of *M. mustelus* collected in the Mediterranean along the coast of Tunisia. He reported that decapods occurred in 59% of stomachs and that teleosts occurred in 31% of stomachs. Other reports list decapods as the major components of the diet of *M. mustelus* (Compagno, 1984; Smale and Compagno, 1997; Cortés, 1999). Taken together, the results of these studies confirm the importance of decapods in the diet of smooth-hound.

In our study, the stomach contents of the smooth-hound indicated that this species could be an opportunistic predator, feeding on variety of prey items, including benthic invertebrates and teleosts, and a wide range of prey sizes and morphologies. Morte *et al.* (1997) suggested that *M. mustelus* in the western Mediterranean were also generalist feeders. Morte *et al.* (1997) found that in 70 specimens examined, prey items consisted of 23 species of benthic crustaceans (mainly *Brachyura* decapods), 11 species of

teleosts (mainly *Sardina pilchardus*, *Engraulis encrasicolus*, *Scomber scombrus* and *Mugil cephalus*), 5 species of bivalves, 3 species of cephalopods and 1 species of gastropods, planktonic crustaceans, annelids and echinoderms. Our study agrees with previous studies on the diet of *M. mustelus* and adds to the body of evidence indicating that this species has fairly consistent diet throughout its range and feeds primarily on decapods crustaceans and lesser extent on teleosts.

The data obtained in this study show that diet composition of *M. mustelus* changes considerably with its growth. Stomach contents analysis indicate a clear trend in prey selection with predator size. Smaller specimens (< 90 cm TL) mainly feed on crustaceans (decapods and stomatopods) that are abundant and have small weights. As size increased the presence of crustaceans diminished in importance and the proportions of teleosts and cephalopods increased. Data obtained of this study on the changes of food content are consistent with those of Smale and Compagno (1997). Namely, Smale and Compagno (1997) reported that smaller specimens of *M. mustelus* consume more bottom-living crustaceans while with the increase in length (TL ≥ 80 cm) they switch cephalopods. Ontogenetic shifts in diet are common in sharks (Lowe *et al*., 1996). There is evidence that size differences reflect changing food preference with growth and the ability of large individuals to capture larger prey. Mean prey size increases with increasing predator size in order to optimize the energy per unit effort (Ware, 1972; Ross, 1977; Stoner and Livingston, 1984). Trophic ontogeny in smooth-hound could be explained in terms of fish morphology. The width and gape of mouth are linearly related to the fish size (Ross, 1978; Stoner, 1980) and increased body and mouth size permit fish to capture a broader range of prey size and prey types. Such changes in food habits with fish size could decrease intraspecific competition (Langton, 1982).

Little seasonal variation in the diet of smooth-hound was noticed within study area. Values of Schoener's index (> 0.60) indicated high dietary overlap between seasons. The small variations of the main prey items between seasons contributed to the high level on inter-season proportional overlap. Decapod crustaceans dominated the diet composition throughout the year, particularly in summer. Increased decapods consumption during the summer coincides with the period of the new recruits of many decapods species, which may be present in the high densities (Robertson, 1984; Grubišić, 1988).

In conclusion, various prey groups, with wide range of sizes and morphologies found in the smooth-hound stomachs indicated that *M. mustelus* could be an opportunistic predator. Decapods were the most important prey in all season as well as in specimens up to 110 cm TL. In addition, teleosts constituted main food in larger specimens.

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